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AAMP: thoughts on metrics for the Asian-Australian monsoon

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Outline

- Why are we doing this?
- Large-scale and local aspects all important for the monsoon.
- Met Office assessment exercises.
- Decadal variability (of teleconnections).
- Towards process-based metrics?
- Winter monsoon/AustM

What might diagnostics/metrics be measuring?

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- Understanding observations (the processes themselves in addition to what the monsoon and its variability looks like) [I don't think this is the focus here]
- Model performance relative to observations
- Model comparison (ultimately, can particular models be trusted more than others; weighting of forecasts/future projections)
- Incremental improvements in individual models [this aspect is important: often model development proceeds, for various reasons, without paying attention to deterioration of the monsoon, blocking, whatever]
- Are they suitable for use in climate change comparisons?

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Monsoon climate in HiGEM

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- Large-scale flow looks quite reasonable yet complete absence of rainfall over India, as in HadGEM1

→ Need to assess both large and local scales.

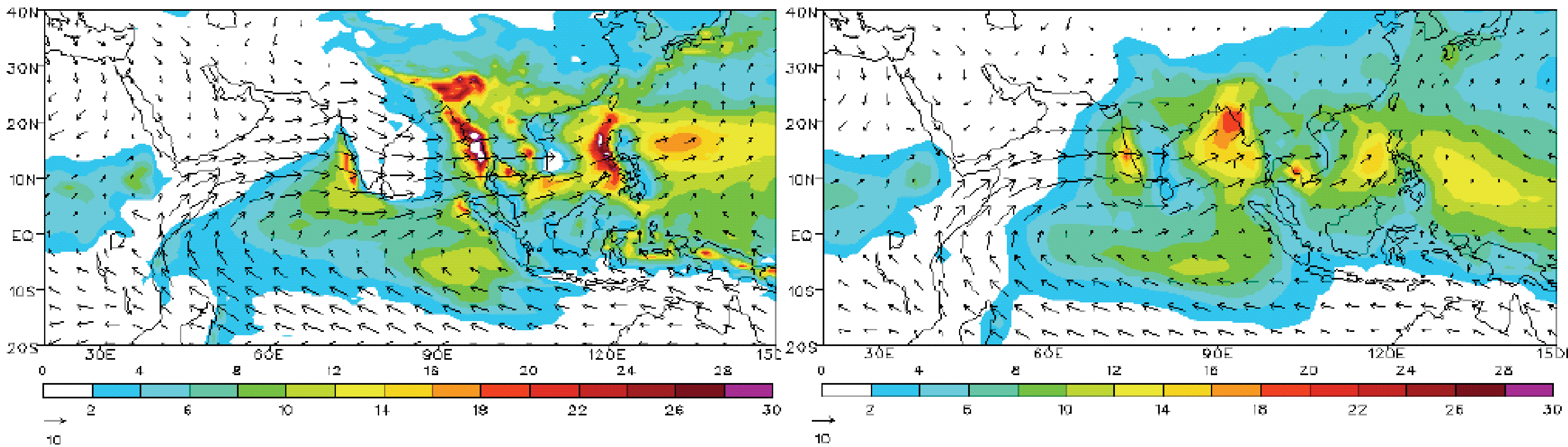

Figure 14. JJA 850 hPa winds and precipitation from HiGEM (left) and ERA40/CMAP (right). Reference vector is 10 ms^{-1} and contour interval is 2 mm day^{-1}.

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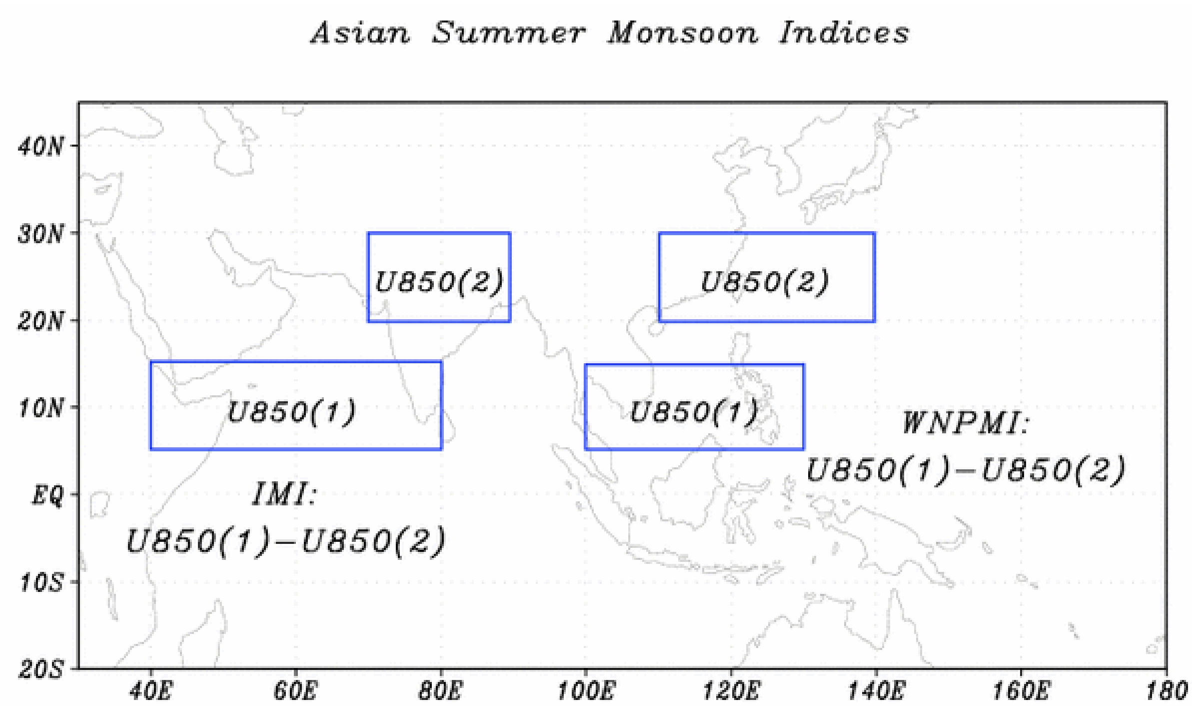
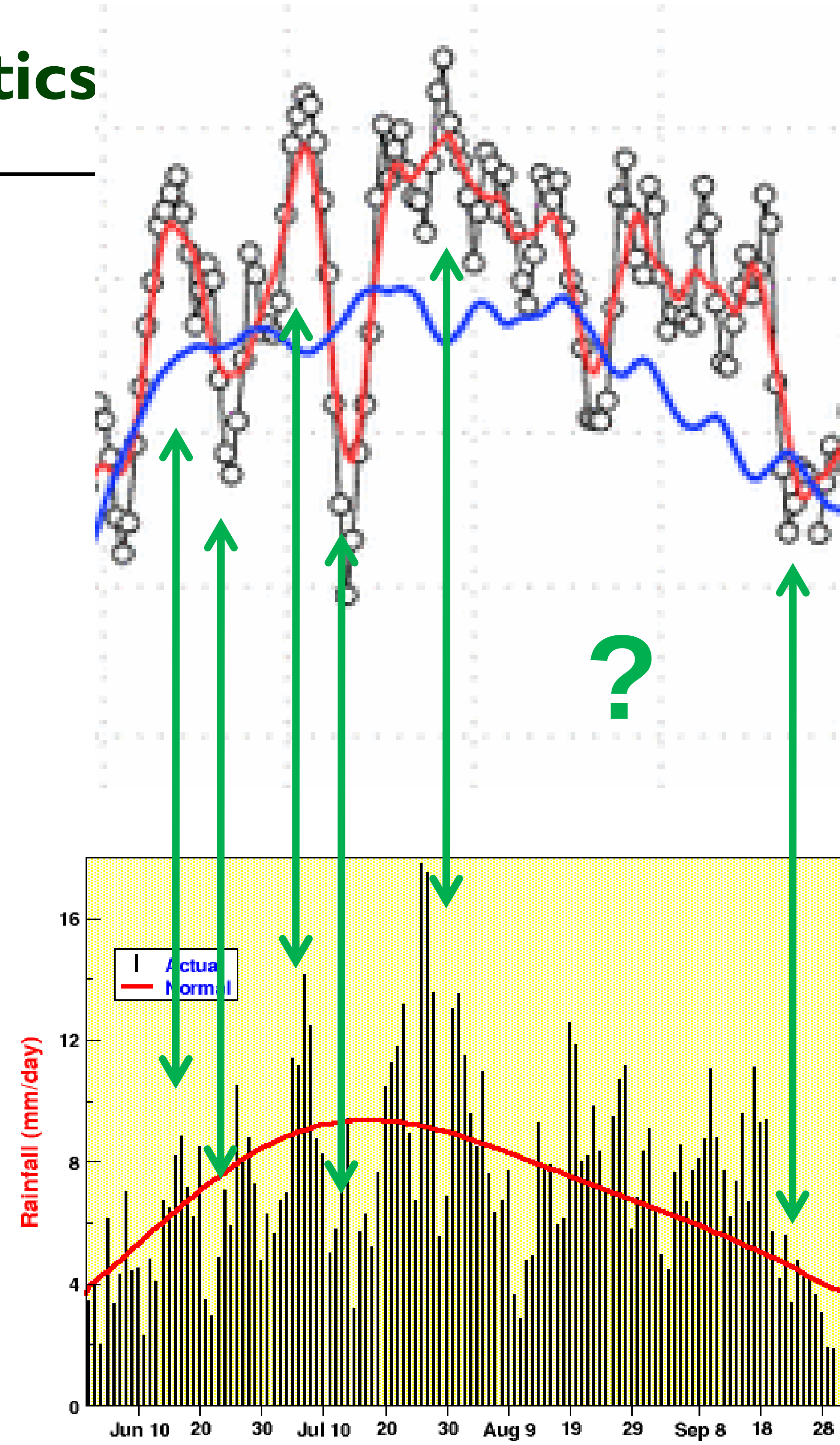
Relevance of circulation diagnostics

- Excellent agreement on intraseasonal timescales between Wang & Fan (1999) meridional shear index and all-India rainfall activity in 2010.





Met Office use of metrics in model development

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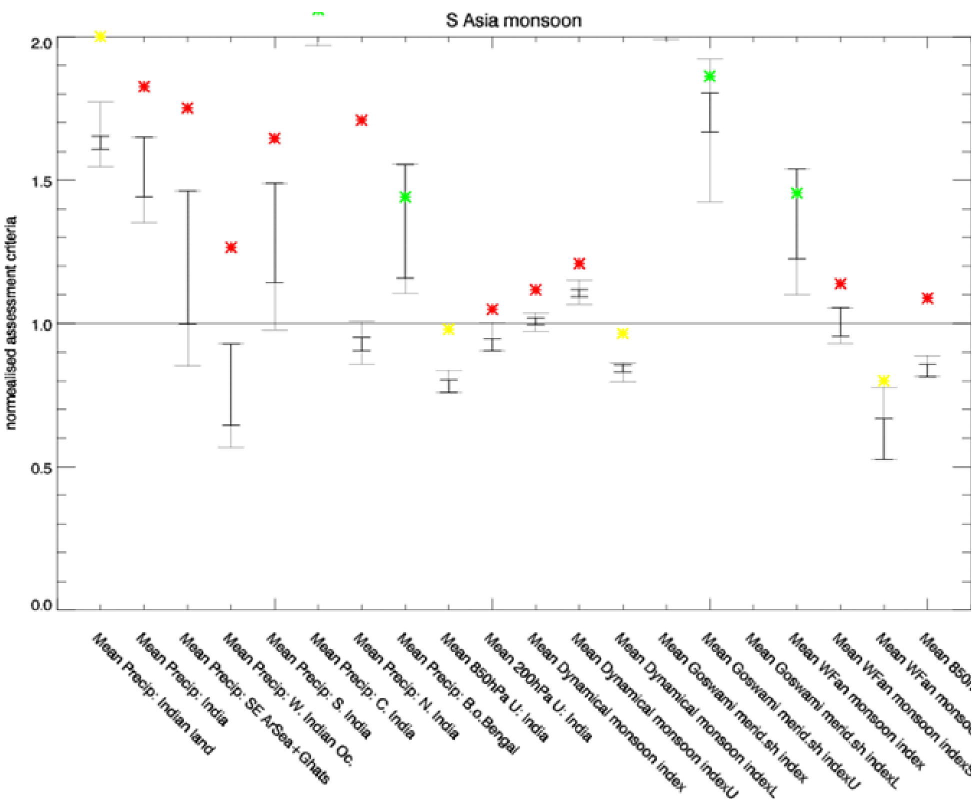
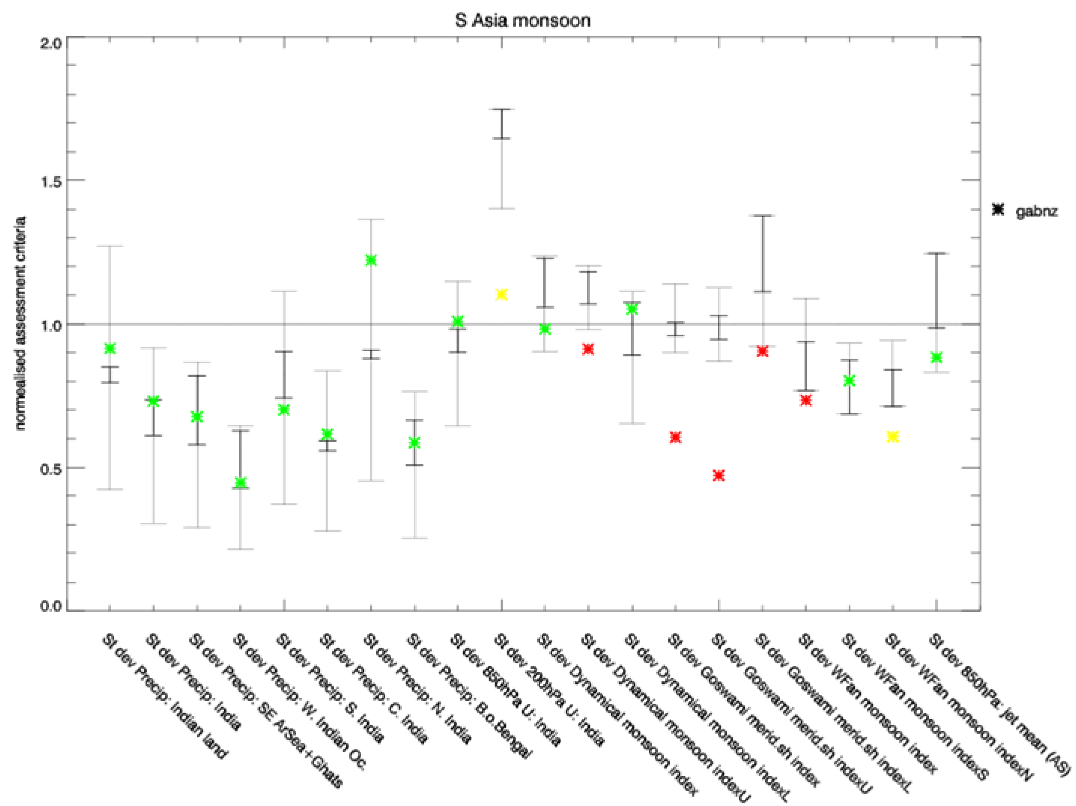
- Suite of metrics used to test incremental versions of models through the development cycle.
- Models assessed on range of mean, variability and teleconnection metrics against range of observations.





MORPH3 assessment

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http://ncas-climate.nerc.ac.uk/pmwiki/monsoon_wg/index.php/Main/FinalMORPH3AssessmentResults-March2010

aicvx: HadGEM3-AO N96L85 ORCA1 model (baseline: HadGEM2-AO N96L38)

see detailed results of submetrics here

CLIM	*Summer monsoon precipitation (8)*	*Summer monsoon winds (17)*	*Seasonal cycle (7)*	*Monsoon onset and retreat (2)*	*Land Surface temperature (3)*	*North Indian Ocean SSTs (14)*	*Soil moisture*	*Winter monsoon*
VAR	*Interannual variability of summer monsoon precipitation (2)*	*Interannual variability of dynamical monsoon indices (9)*	*Intra-seasonal variability of summer monsoon (6)*	*Monsoon depressions (3)*	*Indian Ocean Dipole (6)*	*Tropical cyclones (8)*	*Extremes (8)*	*Interannual variability of Winter Monsoon*
TELE	*ENSO-monsoon teleconnection (3)*	*Arabian Sea-monsoon teleconnection (2)*	*Indian Ocean Dipole-monsoon teleconnection (6)*	*Indian Ocean Dipole-ENSO teleconnection (3)*	*European/Tibetan/Asian winter/spring snhttp://www-hc/~hadlv/mean_wind850_airxv_v_ageyb.pngow-monsoon teleconnection*	*MJO and monsoon onset*		

http://www-hc/~hadlv/mean_wind850_airxv_v_ageyb.pnghttp://www-hc/~hadlv/mean_wind850_airxv_v_ageyb.png

aisas: HadGEM3-AO N216L85 ORCA025 model (baseline: HadGEM2-AO N96L38)

see detailed results of submetrics here

CLIM	*Summer monsoon precipitation (8)*	*Summer monsoon winds (17)*	*Seasonal cycle (7)*	*Monsoon onset and retreat (2)*	*Land Surface temperature (3)*	*North Indian Ocean SSTs (14)*	*Soil moisture*	*Winter monsoon*
VAR	*Interannual variability of summer monsoon precipitation (2)*	*Interannual variability of dynamical monsoon indices (9)*	*Intra-seasonal variability of summer monsoon (6)*	*Monsoon depressions (3)*	*Indian Ocean Dipole (6)*	*Tropical cyclones (8)*	*Extremes (8)*	*Interannual variability of Winter Monsoon*
TELE	*ENSO-monsoon teleconnection (3)*	*Arabian Sea-monsoon teleconnection (2)*	*Indian Ocean Dipole-monsoon teleconnection (6)*	*Indian Ocean Dipole-ENSO teleconnection (3)*	*European/Tibetan /Asian winter/spring snow-monsoon teleconnection*	*MJO and monsoon onset*		

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Climatology		
1. Summer monsoon precipitation: subjective combination of 1.1-1.7 (Richard Levine)	*Fit for purpose determined by:* *max/min interquartile ranges of IITM+CMAP+GPCP*	*Fit for purpose determined by:* *70-130% of obs mean*
1.1 Total Indian region precip JJAS		
1.2 Total Indian land precip JJAS		
1.3 Central Indian land precip JJAS		
1.4 North Indian land precip JJAS		
1.5 South India land precip JJAS		
1.6 West equatorial Indian Ocean precip JJAS		
1.7 SE Arabian Sea + W Ghats precip JJAS		
1.8 Bay of Bengal precip JJAS		
2. Summer monsoon winds: combination of 2.1-2.11 (Richard Levine)	*Fit for purpose determined by: ERA40 interquartile ranges*	
2.1 850mb zonal winds: RMS error over AS/India/BoB area (JJAS)	*Note: fit for purpose here is within 25% of ERA40 climatological mean RMS,* *maximumum inter-reanalysis (MERRA-ERA40 and JRA-ERA40) RMSE is 12% of ERA40 RMS*	Note: only just inside the quite wide acceptability criteria.
2.2 position of monsoon jet core over Arabian Sea (JJAS)		
2.3 peak of monsoon jet core over Arabian Sea (JJAS)		
2.4 mean meridional width of jet over Arabian Sea/W eq Indian Ocean		
2.5 mean strength of monsoon jet over Arabian Sea		Bit worse, but within model internal variability, note that both HG3 and HG2 are quite poor.
2.6 mean curvature of low-level monsoon flow		A lot worse, much too zonal over southern tip of India and BoB
2.7 peak curvature of low-level monsoon flow		see above
2.8 200mb zonal winds over Webster-Yang region (JJAS) - upper level DMi		Note : overall the metric is RED as (1) 200mb winds over WY region are too strong in Arabian Sea, RED compared to HG2 (2) there is an increase in the error over the upper level westerly jet (around 30N, which is not part of the Webster-Yang region) (3) however there is an improvement as a large area of divergence over the equator is removed associated with the reduction of W eq Indian Ocean precipitation
2.9 850mb zonal winds over Webster-Yang region (JJAS) - lower level DMi		
2.10 Dynamical monsoon index (DMi): lower-upper level components		HG2 and HG3 both inside range
2.11 Longitudinal extension of jet into West Pacific	*For future assessments*	
2.12 Goswami meridional shear index		
2.13 Goswami meridional shear index - lower tropospheric component		
2.14 Goswami meridional shear index - upper tropospheric component		
2.15 Wang and Fan Index		Worse than HG2 and outside model internal variability
2.16 Wang and Fan Index - southern component		
2.17 Wang and Fan Index - northern component		Worse than HG2 and outside model internal variability. This is due to lack of monsoon trough

3. Seasonal cycle: combination of 3.1-3.2 (Andy Turner)	
3.1 precipitaion	
3.2 U/V winds	
4. Monsoon onset and retreat: combination of 4.1-4.2 (Richard Levine)	
4.1 Monsoon onset date	
4.2 Monsoon retreat date	
5. Land Surface temperature: combination of 5.1-5.2 (Andy Turner)	
5.1 1.5m temperature: JJAS	
5.2 1.5m temperature: DJF	
5.3 Diurnal temperature ranges	*For future assesments*
6. North Indian Ocean SSTs: combination of 5.1-5.11 (Richard Levine)	
6.1 Arabian Sea SST seasonal cycle range	
6.2 Arabian Sea SST seasonal cycle max	
6.3 Arabian Sea SST seasonal cycle min	
6.4 Arabian Sea SST: annual mean	
6.5 Arabian Sea SST: DJF mean	
6.6 Arabian Sea SST: MAM mean	
6.7 Arabian Sea SST: JJA mean	
6.8 Arabian Sea SST: SON mean	
6.9 Bay of Bengal SST seasonal cycle range	
6.10 Bay of Bengal SST seasonal cycle max	
6.11 Bay of Bengal SST seasonal cycle min	
6.12 Bay of Bengal SST: annual mean	
6.13 Bay of Bengal SST: DJF mean	
6.14 Bay of Bengal SST: MAM mean	
6.15 Bay of Bengal SST: JJA mean	
6.16 Bay of Bengal SST: SON mean	
7. Soil moisture: *For future assesments*	*For future assessments*
8. Winter monsoon: *For future assesments*	*For future assessments*
9. Extremes: *For future assesments*	*For future assessments*

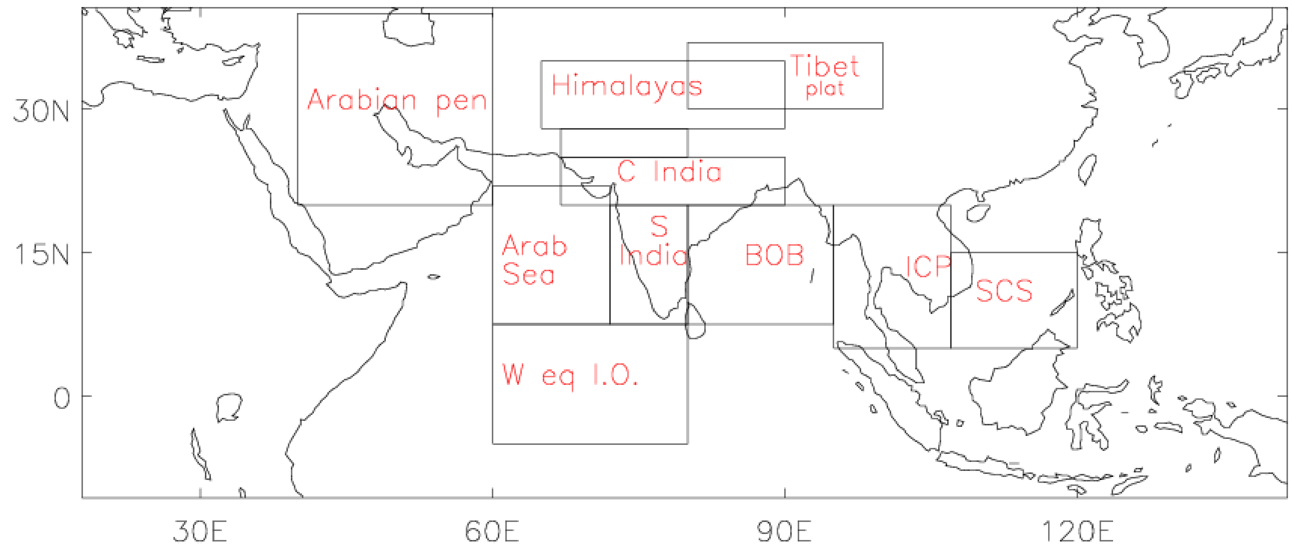
Variability	Fit for purpose determined by: max/min interquartile ranges of IITM+CMAP+GPCP	Fit for purpose determined by: 70-130% of obs mean
1. Interannual variability of summer monsoon precipitation (Richard Levine)		
1.1 Indian land precip		
1.2 West equatorial Indian Ocean precip		
2 Interannual variability of dynamical monsoon indices	Fit for purpose determined by 50-150% of ERA40	Fit for purpose determined by max/min SD of 20-year window of ERA40
2.1 Goswami meridional shear index		
2.2 Goswami meridional shear index - lower tropospheric component		
2.3 Goswami meridional shear index - upper topospheric component		
2.4 Webster-Yang dynamical monsoon index		
2.5 Webster-Yang dynamical monsoon index - lower tropospheric component		
2.6 Webster-Yang dynamical monsoon index - upper tropospheric component		
2.7 Wang and Fan Index		
2.8 Wang and Fan Index - southern component		
2.9 Wang and Fan Index - northern component		
3. Intra-seasonal variability of summer monsoon (Nick Klingaman)		
3.1 Northward propagation (active/break cycles) over E eq Indian Ocean		
3.2 Northward propagation (active/break cycles) over Bay of Bengal		
3.3 Total sub-seasonal variability over entire monsoon domain		
3.4 Westward propagation - W Pacific		
3.5 Westward propagation - Bay of Bengal		
3.6 Measure of propagation	for future assessments	
4. Monsoon depressions: subjective combination of 4.1-4.3 (Richard Levine)		
4.1 Mean track density over Bay of Bengal (JJA)		
4.2 Mean track density over India (JJA)		
4.3 Mean track intensity over India+BOB region (JJA)		
5. Indian Ocean Dipole (Richard Levine)		
5.1 Dipole Mode Index (DMi)		
5.2 DMi - western component		
5.3 DMi - eastern component		
5.4 Correlation with zonal wind anomalies - total IOD		
5.5 Correlation with zonal wind anomalies - western component		
5.6 Correlation with zonal wind anomalies - eastern component		

6. Tropical cyclones (Ruth McDonald)	
6.1 Indian Ocean track density: JJA	
6.2 Indian Ocean track density: DJF	
6.3 Indian Ocean track density: MAM	
6.4 Indian Ocean track density: SON	
6.5 Indian Ocean track intensity: JJA	
6.6 Indian Ocean track intensity: DJF	
6.7 Indian Ocean track intensity: MAM	
6.8 Indian Ocean track intensity: SON	
7. Extremes (Lizzie Kendon)	
7.1 Probability of dry day (<0.1mm/day): DJF	
7.2 95th percentile of wet day precipitation: DJF	
7.3 Probability of dry day (<0.1mm/day): MAM	
7.4 95th percentile of wet day precipitation: MAM	
7.5 Probability of dry day (<0.1mm/day): JJA	
7.6 95th percentile of wet day precipitation: JJA	
7.7 Probability of dry day (<0.1mm/day): SON	
7.8 95th percentile of wet day precipitation: SON	
8. Indian Winter Monsoon	for future assessments

Teleconnections		
1. ENSO-monsoon teleconnection		
1.1 ENSO-monsoon teleconnection: Nino3 region		
1.2 ENSO-monsoon teleconnection: Nino3.4 region		
1.3 ENSO-monsoon teleconnection: NW Pacific		
2. Arabian Sea-monsoon teleconnection (Richard Levine)	green: but note wide ranges for coupled model..	
2.1 Arabian Sea - Indian rainfall (partial correlation with Nino3 mean)		
2.2 Arabian Sea - North Indian rainfall (partial correlation with Nino3 mean)		
3. Indian Ocean Dipole-monsoon teleconnection (Andy Turner)		
4. Indian Ocean Dipole-ENSO teleconnection (Andy Turner)		

Some dangers

- Danger of obscuring detail through cancellation of positive and negative biases → pattern correlation, RMSE etc are useful.
- Should avoid metric overlap.
- IAV/ISV may itself depend on mean state and thus be “correct” for the supplied mean state [may be discounting a given model twice for the same reason].



Decadal variability in teleconnections

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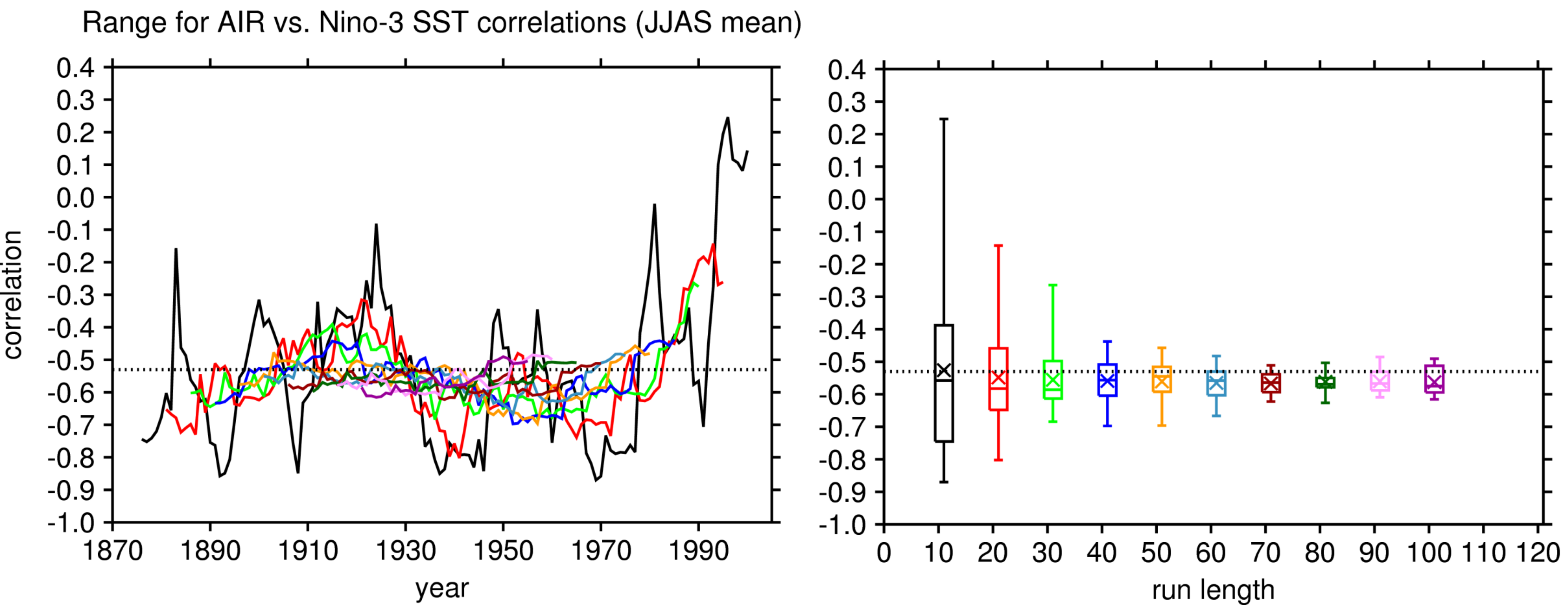
- Sampling: what integration length is enough? Large natural/internal variability in ENSO, monsoon-ENSO teleconnection.



Decadal variability in teleconnections

Turner *et al*. (2007). Wittenberg *et al*. (2009)

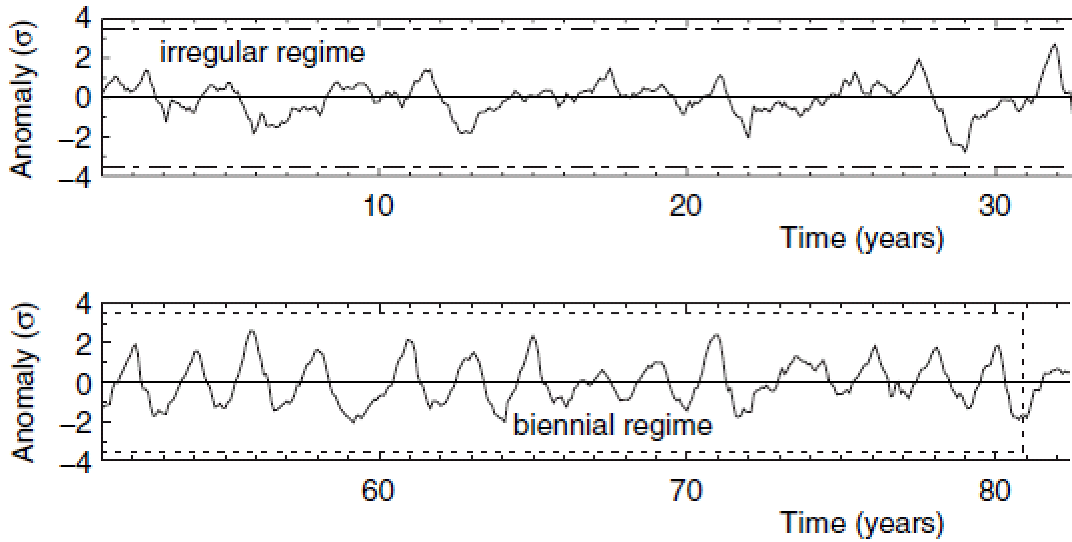


Figure 1. Timeseries of seasonally-adjusted Niño-3 SST anomalies in the HadCM3IPFA 2 :
are indicated: irregular (dot-dashed) years 1–35 inclusive and biennial

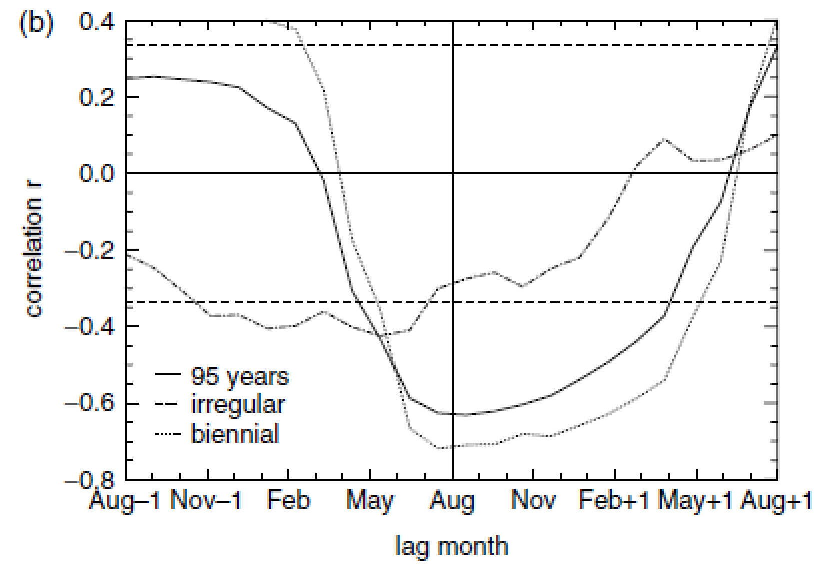


Figure 11. Lag-correlations between Niño-3 SST anomalies and summer (JJAS) monsoon indices (a) the DMI, (b) All-India rainfall (for definition see TIS07). Outside the dashed lines, the regime correlations are significant at the 95% level.

Wittenberg (2009)

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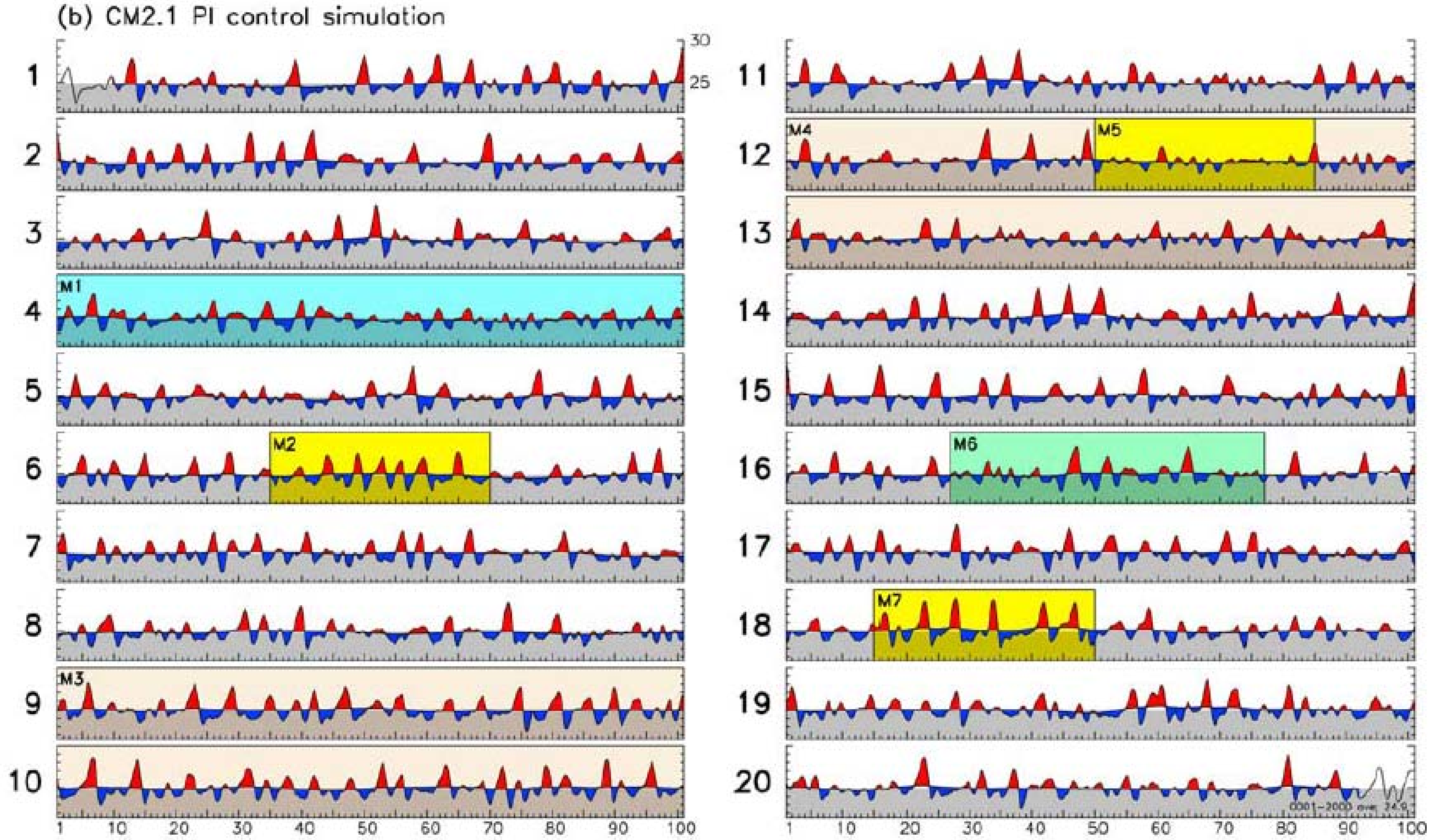

Figure 1. SST (°C) averaged over the NINO3 region (150°W–90°W, 5°S–5°N), for (a) the ERSST.v3 historical reconstruction of *Smith et al.* [2008], and (b) the 20 consecutive centuries (numbered) from the CM2.1 pre-industrial control run. Red/blue shading highlights departures of the running annual-mean SST from the multidecadal background state, where the latter is obtained via a 211-month triangle smoother which transmits (25, 50, 75)% of the time series amplitude at periods of (15, 20, 30) yr. Unshaded time series ends in Figure 1b indicate the half-width of the triangle smoother; ends of the observed time series in Figure 1a are zero-padded prior to smoothing. The top of the gray bar is the long-term mean, indicated at the bottom right of each plot. Labeled epochs are discussed in the text.

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Process based metrics?

Example: Goswami/Xavier deltaTT index. Gives information about thermal temperature gradient vs. high data volumes required for calculation.

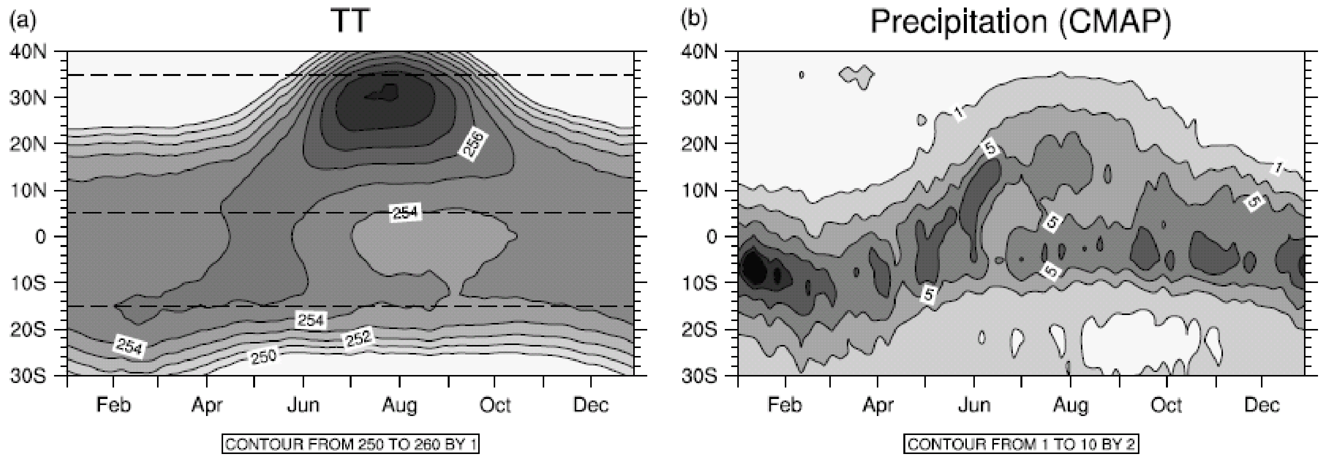

Figure 1. Time–latitude evolution of climatological mean (a) TT (K) and (b) precipitation (mm day^{-1}) averaged over the longitudes 40–100 °E. The dashed lines in (a) indicate the latitudinal zones for which averaging has been done in the computation of ΔTT.

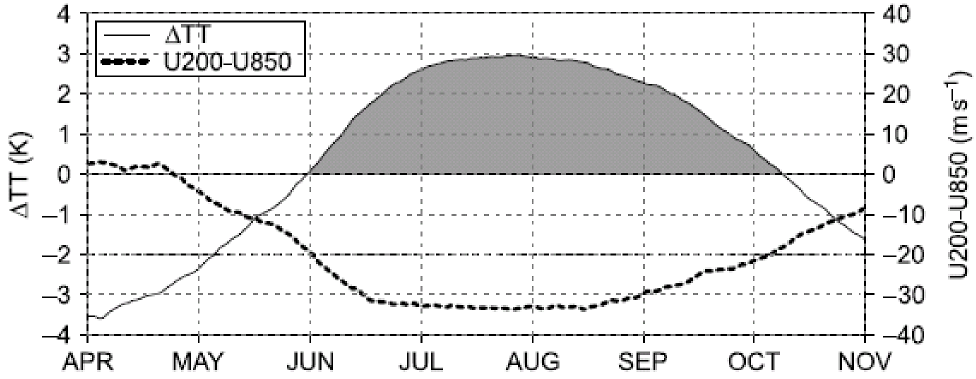

Figure 2. Evolution of climatological values of ΔTT (solid line, scale on the left) and of the climatological mean vertical shear of zonal winds ($U_{200}-U_{850}$) averaged over (50–95 °E, 0–15 °N) (dotted line, scale on the right). The shaded area under the ΔTT curve represents the climatological value of our thermodynamic index of the seasonal mean monsoon.

Winter monsoon consideration

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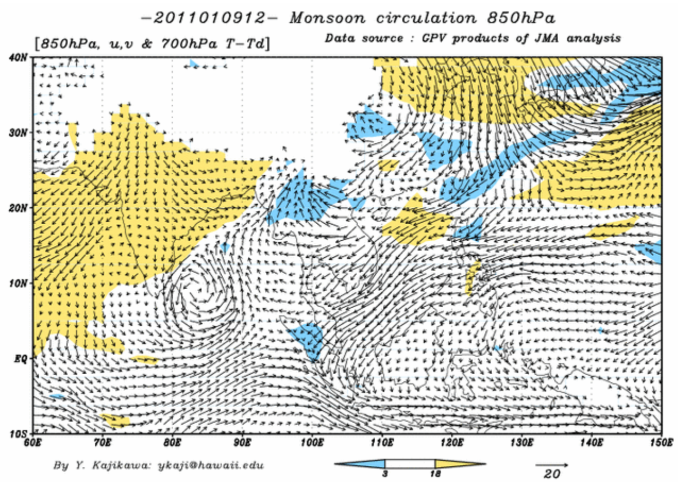
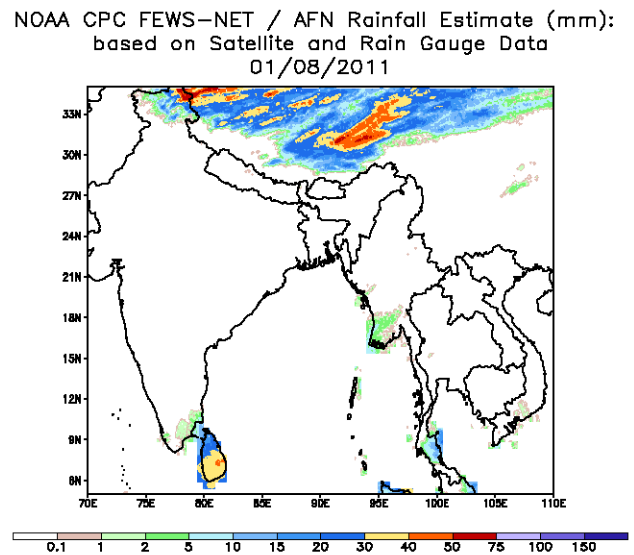
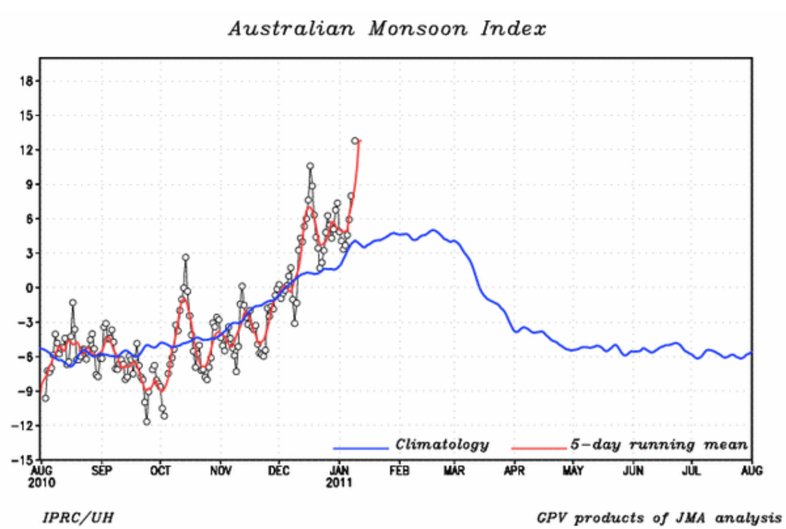
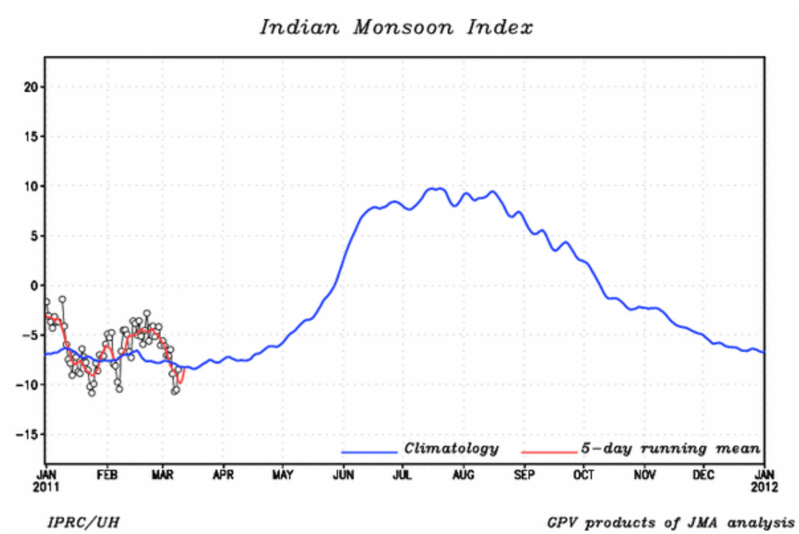
Wang & Fan indices, Sri Lankan flooding 2011: event likely on too local a scale to be covered by a circulation index.









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Strategies for diagnostic selection (CLIVAR MJOWG)

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- Showing the important and essential features of BSISV and its dynamics but simple enough to understand/calculate.
- Defined to show eastward propagation in the summer/winter equatorial Pacific; northward propagation in summer.
- Observation comparison based on satellite or reanalysis data, using >1 data source (discrepancies between models themselves or models and observation are larger than between observed data however).
- Supplementary diagnostics, *e.g.*, of the mean state, or to show multiscale interactions.
- Two-level diagnostics.

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A level-1 and level-2 approach?

- As in the CLIVAR MJOWG.
- Ease of use is emphasized, as simple and uniform as possible for various regions.
- Only once level-1 metrics have been confirmed in models should analysis of level-2 metrics begin (more comprehensive/rigorous, perhaps multi-variate, more process-based etc).

Caution on the use of metrics

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- Good performance at one aspect of the monsoon doesn't necessarily translate to another, e.g., models with the most physically realistic BSISV don't necessarily score best in simple metrics, *e.g*., pattern correlation with observations (Sperber & Annamalai, 2008).
- Real danger of unwarranted importance to given metric being attached without awareness of limitations (Gleckler *et al*., 2008): --> advise against misuse of metric/issue caveats.

Missing elements

- EASM: evolution of WNP AC / advancement of Baiu-Meiyu-Changma.
- We are addressing seasonal predictability but what of ISV- performance at coordinated hindcasts? Also ISV-IAV relations (but I don't think we understand those enough to make judgements of models).
- Variation of ENSO type. Use of TNI (e.g., Krishna Kumar et al., 2005).